

DISSEMINATION DESIGN OF A 3D DOCUMENTED ARCHAEOLOGICAL FEATURE IN EPHEOS

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ABSTRACT:

The paper presents different forms of documentation of a Late Antique and Early Byzantine water-powered workshop and milling complex in what is commonly known as Terrace House 2 in Ephesos, Turkey. The entire complex was documented by means of 3D laser scanning in 2009 and 2010. Geometrical data were processed and used in the form of a point cloud in the archaeological analysis. Narrow parts, complex structures, and small rooms of the well-preserved feature were surveyed efficiently using a 3D laser scanner. Additionally, panoramic images were captured. They offered the possibility to colour the point cloud, thus helping to identify and understand the feature better in the model. The developed consistent 3D point cloud of the entire feature provided the spatial data for analyses, reconstructions and technical drawings, such as ground plots and sectional views for publications. In order to address specific questions, e.g. to determine the course of the chute, or the size and position of the water-wheels, it was essential to be able to work with complete geometric data. For that purpose the data were exported from original files, using a free software plugin, and made usable in an internet browser. The interface is easy to operate and allows measurement and marking of 3D distances and coordinates of single points, within one scanner position. These can be saved and exchanged. In addition, using this technique a selection of the 3D data will be made available to the general user.

1. INTRODUCTION

The water-powered workshop and milling complex in the so-called Terrace House 2 in Ephesos, Turkey, is one of the largest known workshops using waterpower in Late Antique and early Byzantine times (other known water-mills: Athens: Parsons, 1936; Frantz, 1988; Thompson, 1960; Spain, 1987; Barbegal: Benoît, 1940; Leveau, 2006; 2007; Chemtou: Hess, 1992; Röder & Röder, 1993; Nahal Tanninim: Ad et al., 2005; Rome: Bell, 1994; Schiøler & Wikander, 1983; Wilson, 2000; 2001; 2003; compilation: Spain, 2008). This archaeological feature was excavated between 1970 and 1983 (Vetters, 1981: Fig. 10; 1985: 8 Fig. 2, Ladstätter, 2002: 12–13, and unpublished field notebooks). However, due to the precious findings and features of the antique periods which were found in its direct vicinity and underneath the workshop- and milling complex it was up to now not studied in its entirety or detail (Pülz (2010: 541) referring to research into the entire city of Ephesos, Jobst, 1977; Krinzinger, 2010; Rathmayr, in press). The results of the archaeological research will be published in a monograph (Wefers in prep.).

Considering that it was not possible to carry out the documentation work and research exclusively on site in Ephesos, three opposing needs had to be considered: fast recording time, high accuracy, and a manageable volume of data. Therefore, it was decided to use a terrestrial 3D

laser scanner to produce a virtual 3D model for publication on a web-based platform. However, another important aim was to produce two-dimensional plans and sections for publication in print, in journals and books dealing with the results of the archaeological research. The objective was to convey, on the one hand, the current condition of the water-mill complex, and on the other hand, the archaeological interpretation by means of reconstruction drawings.

2. ARCHAEOLOGICAL BACKGROUND

Ephesos is a famous antique city in western Turkey. Today it is located some 5.5 kilometres away from the coast-line, but in classical times, in antiquity, and possibly also in early Roman times, the city faced the sea. In fact, the natural bay silted up, causing a shift of the coast-line further to the West, presumably from Roman times onwards. However, until Byzantine times Ephesos could be reached by ship, since this process of silting up was finally bypassed by building an artificial channel probably in the first century AD^{*}. The channel connected the harbour of Ephesos with the open sea (Fig. 1; Engelmann, 1996: 134; Kraft et al., 2007: especially 135–145; Külzer, 2010: 521; Ladstätter,

^{*}) Thanks to recent palaeogeographical analyses undertaken under the direction of Prof. Dr. H. Brückner of the Institute of Geography at the University of Cologne, the construction of the

harbour channel can be dated to the late first century AD. Information courtesy of Priv.-Doz. Mag. Dr. S. Ladstätter of the Austrian Archaeological Institute.

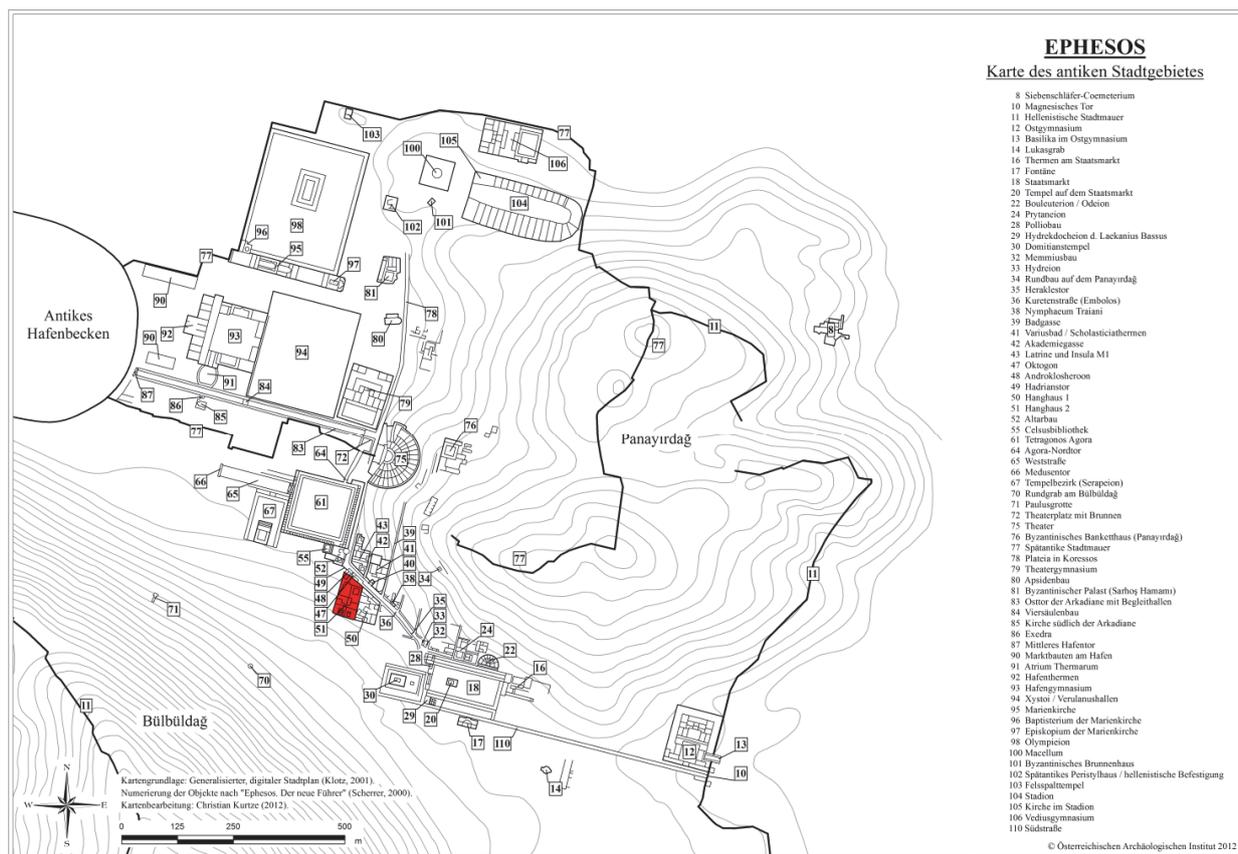


Figure 1. Map of the ancient city of Ephesos. The building known as Terrace House 2 is highlighted in red.
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2010: 501–502). Figure 1 shows the so-called Terrace House 2, highlighted in red, where the water-powered milling- and workshop-complex is situated. The house is located on the northern slopes of the Bülbüldağ and is only one insula of many more located to the east and west, as well as south of Terrace House 2.^{*)}

Terrace House 2 consists of seven interlaced Roman dwellings with several construction phases and all dwellings are decorated with marble incrustations, mosaics and wall paintings and the excavations revealed well-preserved finds of furniture. These luxurious dwellings were destroyed by a series of earthquakes in 262 AD, and were not rebuilt (Ladstätter, 2002). Presumably shortly after these devastating events water-mills and workshops were built on the ruins, sometimes by using the remains of old walls as foundation, sometimes built directly above the basement which must have required removing all debris first (Wefers / Gluhak, in press, Wefers, in prep.). Due to the multiple construction phases from the antique periods to the early Byzantine times terrace house 2 is a complex feature difficult to interpret and understand.

All in all eight workshops are preserved (Fig. 2). They had access to a water-wheel and were all connected to at least one other water-wheel by a chute. The mills housed the gearing in a lower storey and the powered machine in an upper storey. Seven of these water-wheels powered

millstones to process cereals. By a rough estimate, it is possible that around 4,000 people could have been supplied with flour produced in the mills every day (Wefers, in prep.). The eighth water-wheel powered a stone sawing machine, cutting four stone slabs at the same time. Experiments with a reconstruction resulted in the estimation that more than 300 sq. metres of slabs could have been produced each year. They were used as stone inlays and for wall incrustations (Mangartz, 2010; Wefers & Mangartz, 2010). Three different building phases of the mills have been identified in the course of archaeological research (Wefers, in prep.).

The milling and workshop complex was constructed in the very heart of Ephesos at the time when the area was busy with activities and buildings were still lavishly furnished and frequently visited. The best possible economic location, close to the Lower Agora and harbour, was chosen (Wefers, in prep.).

3. DOCUMENTATION

3.1 Surveying techniques and data processing

The entire complex is about 100 m long. The difference of 30 m in altitude was used to make the water-wheels work. Documenting this feature was a challenge due to its size and the fact that the constructed walls have survived up to

^{*)} In recent geophysical analyses these insulae were clearly visible. Information courtesy of Priv.-Doz. Mag. Dr. S. Ladstätter of the Austrian Archaeological Institute.

a height of 5 m with only small gaps between each wall in some places.

It was decided to use a terrestrial 3D laser scanner not only due to the challenging working conditions, mentioned above, but also to produce a virtual 3D model. The model is a record of the current state and offers photo-realistic visualisation. It enables further research if and when desired, also in the future.

The entire feature was recorded from more than 100 laser scanner positions, each connected to a panoramic photograph. They were taken from the same spot as the laser scanner-position. A Leica HDS6000 and a Faro

Photon 80 were used to scan a complete panorama (360° horizontal and 270° vertical), producing in average 35 million points for each scanner position. In this project the data acquisition on site needed three weeks including preparations (arrangement of targets, measuring coordinates of the targets in the local georeference system of Ephesos, definition of proper scanner positions), scanning, taking photos, and data control.

In the office the data were processed to build a georeferenced and coloured point cloud taking about 30

Terrace House 2

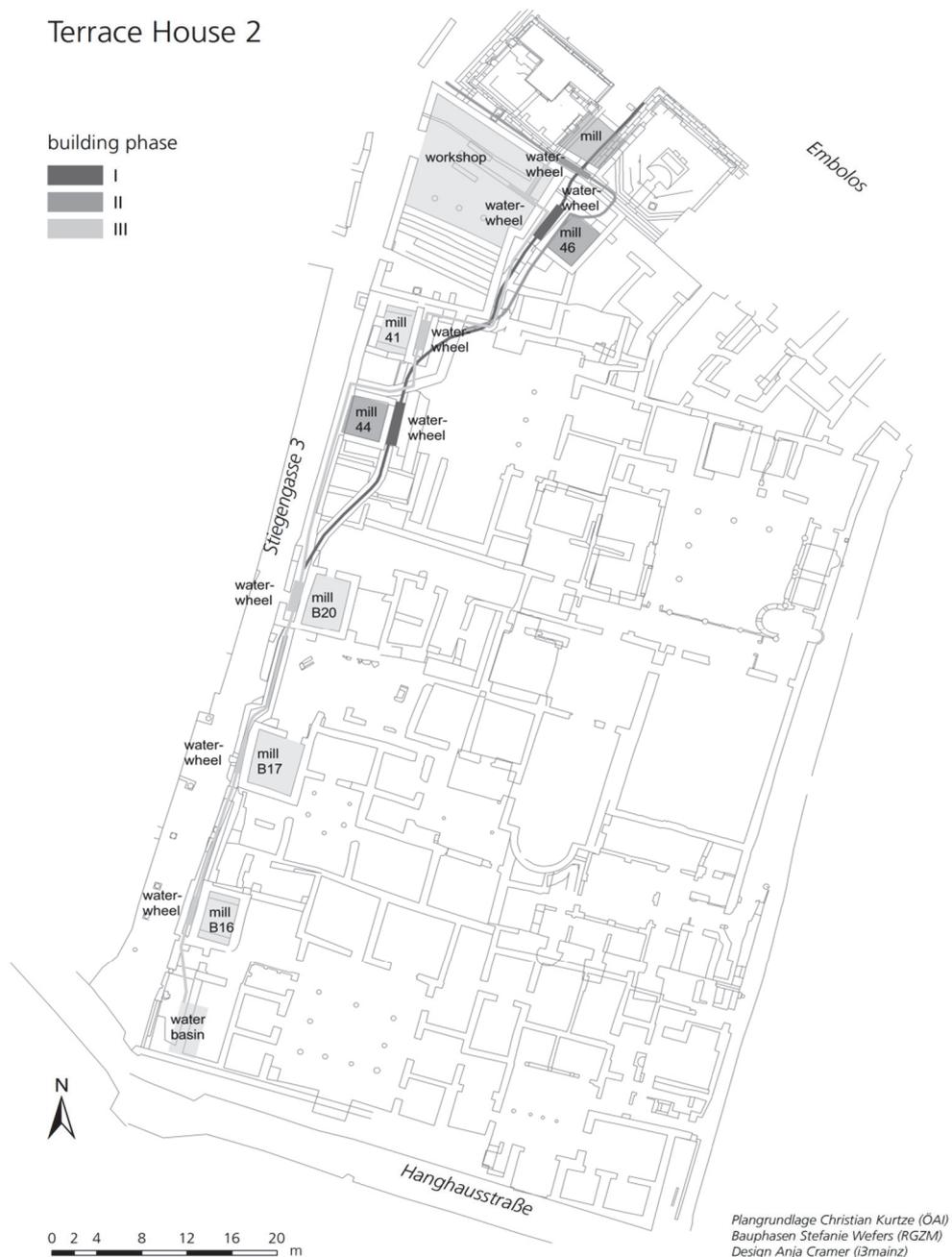


Figure 2. Ground plot of Terrace House 2 showing the eight mills and workshops with associated wheel-races and chutes highlighted in three different grey scales corresponding to each of the three building phases.

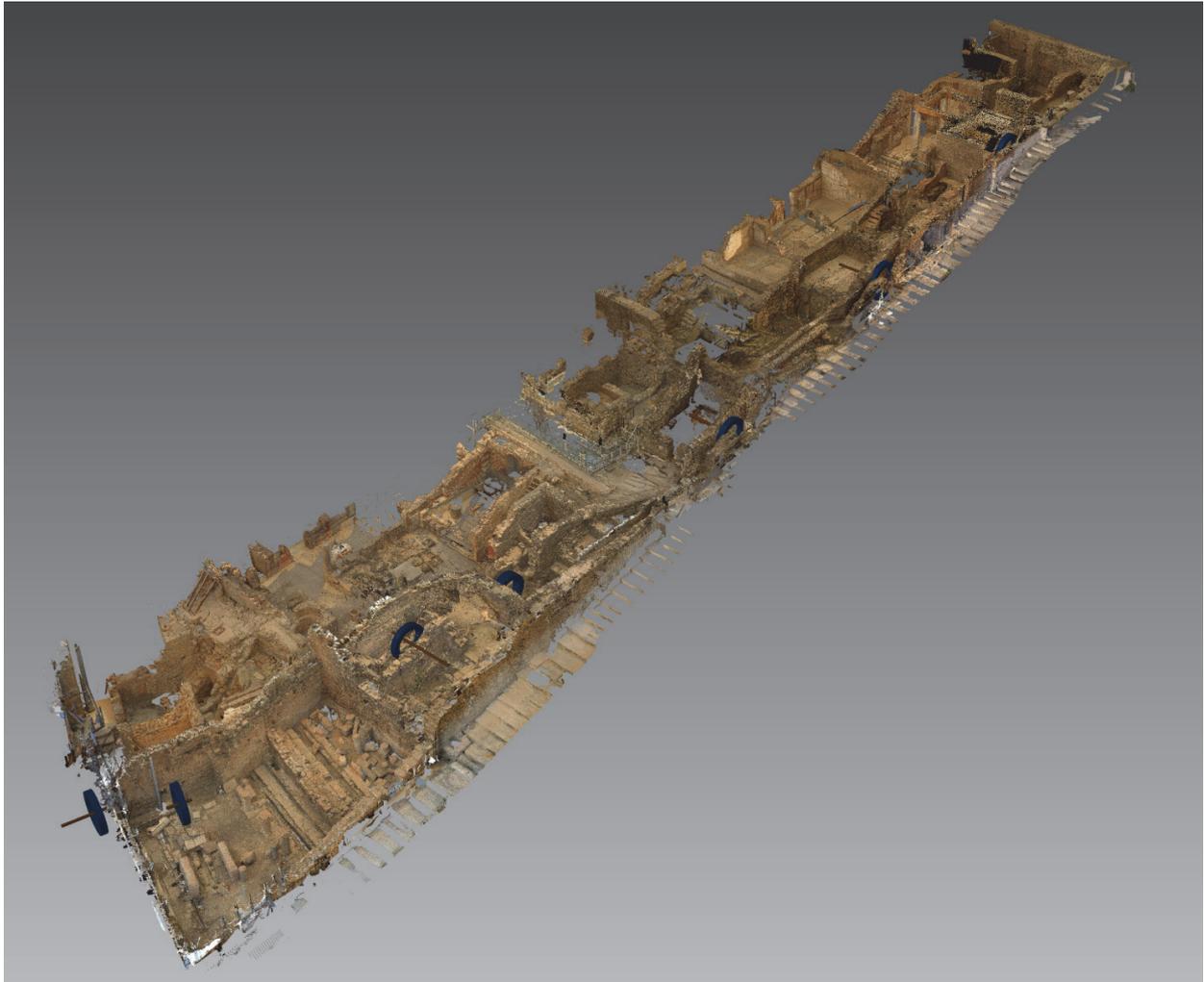


Figure 3. 3D point cloud of the entire workshop and milling complex with roughly shaped water-wheels and axles.

weeks for completion. The following steps were needed: identify the georeferenced targets in each point cloud, points which did not belong to the feature to be deleted in each point cloud, mapping the colour information of the panoramic photographs onto every point of each point cloud, and using the targets to register them to the local georeferencing system of Ephesos.

The result is a colour 3D model of the entire workshop and milling complex (Fig. 3). For ease of handling, the number of points was reduced to a quarter. This means the entire digital model now has about 100 million points (a 60 gigabyte data set).

3.2 Dissemination

The digital point cloud supported the archaeological analysis and was essential for the reconstruction of the workshops, including the width and diameter of each water-wheel.

Eight ground plans, one for each workshop and mill, in scale 1:100, were produced for publication. Furthermore, 19 section drawings were made to document each mill and workshop. One of these sections shows the chutes from the top to bottom, this gives an idea of the construction efforts and conditions in the course of the last, and best preserved, construction phase.

Ground plans (Fig. 4): For a better orientation, a pictogram of the entire Terrace House 2 was designed including a north arrow.

The pictogram highlights in black where the respective ground plan is located. The text underneath the pictogram refers to section drawings of the respective mill or workshop. The plans were produced using the Leica Software extension Leica CloudWorx to load the point cloud into AutoCAD®.



Figure 4. Ground plan of mill B20. Height of main cutting plane 25.50 m MAMSL. Scale 1:100.

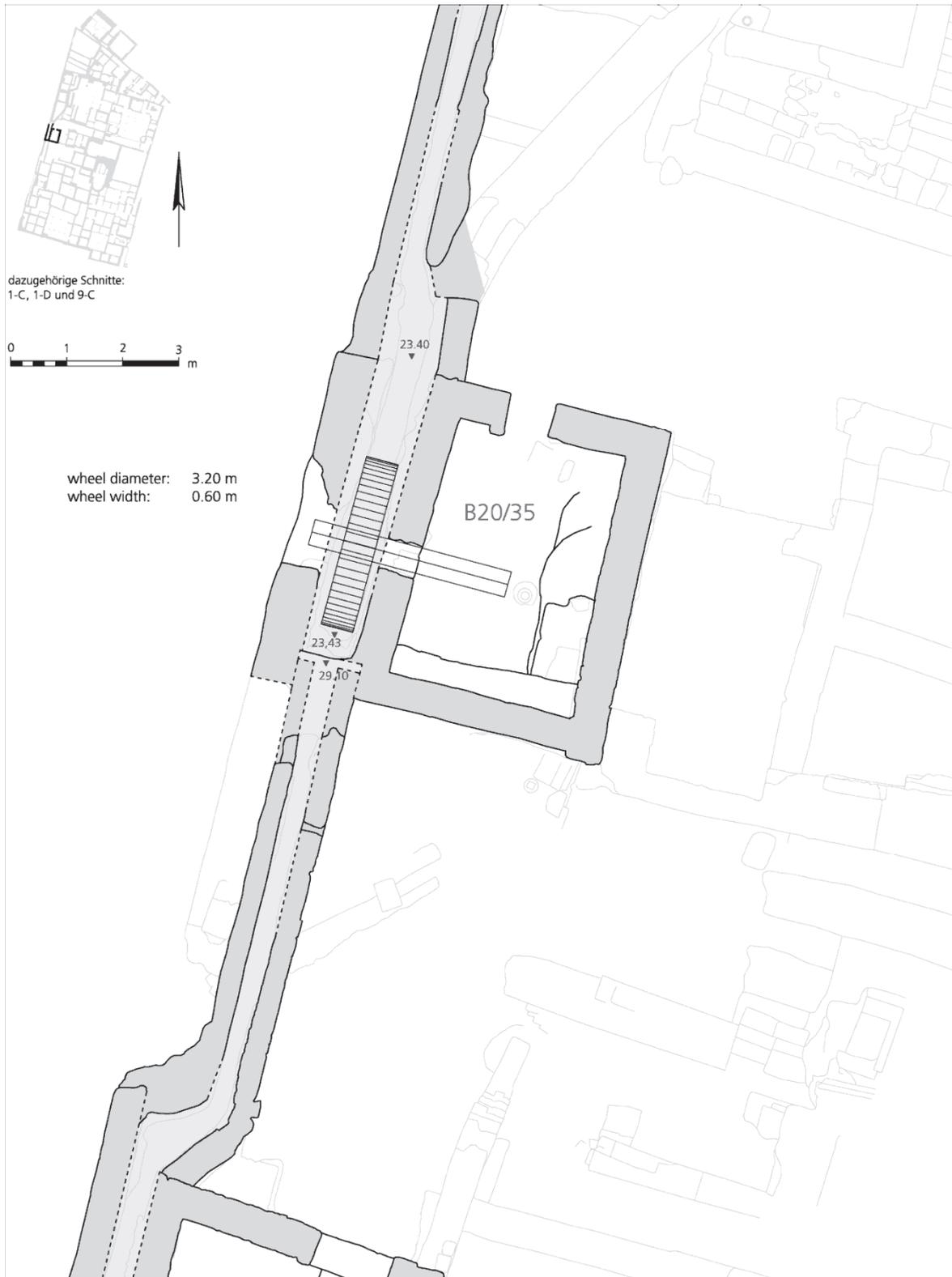


Figure 5. Reconstruction plan of mill B20 displaying the archaeological interpretation including a schematic water-wheel. Scale 1:100.

The next step was to cut this point cloud horizontally on one level and to digitise all relevant information on this level, but also above and underneath. The DIN standard for architectural plans (DIN 1356-1), which cuts a room at 1 m height, is used for all modern houses that can be displayed

by this section, including doors and windows. However, cutting the mills and workshops at 1 m height would have resulted in the omission from the display of the opening between the mill room and wheel-race whose heights vary from one mill to another, sometimes being 4 m above the

ground. Therefore, these openings between wheel-race and millroom set the parameters for each main cut.

Since the walls are no longer always vertically oriented it was decided to display three layers on each ground plan, including all covered structures. Each layer is drawn in a different line width, based on guide lines for architectural plans. The line width of the main section plane is the thickest since it is the most important. On each ground plan the height of this section plane is specified. All structures which are underneath this section plane are drawn in grey; those which are above this level are projected onto it, drawn with a dotted line.

Many elevation spots were added and different fills were used. The first and most eye-catching is the grey fill; it shows walls that are still standing. A dotted fill has been used for floors laid after the excavation in the twentieth century. The dashed line fill indicates areas blocked by heaps of earth, or heavy architectural elements made up of marble, which could not be removed prior to scanning. The cross-hatched fill highlights areas covered by sinter, being evidence for water flowing in the chutes and impinging on the water-wheels.

Based on these ground plans, which document the current feature, reconstruction plans were drawn to show the archaeological interpretation, including a schematic water-wheel (Fig. 5). All elements which are not relevant for this reconstruction are in light grey. The relevant parts are drawn in a thick line, filled either with dark grey (in the case of a cut wall) or light grey (in the case of the ground of a chute).

Section drawings (Fig. 6): The drawing of all sections is based on the same rules as the ground plans, with the exception of the foremost section for which the thickest line and darkest filling have been used. The brighter the lines and fills the farther they are away. Again two sections have been drawn: one showing the structure in its present state, and the other showing the reconstruction, based on the archaeological interpretation, of the mill or workshop, including a schematic water-wheel.

Consolidation of old documentation: The entire Terrace House 2 was excavated from 1967 to 1984 (Wefers, in prep.; unpublished field notebooks). During these 20 years, and also later, many alterations were necessary to conserve and protect parts of the structure. In 2000 a protective canopy was constructed over the entire Terrace House 2. Therefore, essential parts of the water-wheel complex do not exist anymore. However, before removing these parts they were recorded by hand. The old documentation plans were combined with projected point clouds to get information which is no longer available in Terrace House 2. Figure 7, for example, gives the original height of the mill room floor B17 by combining the old hand drawing of the wall with a projected point cloud of the same wall (Wefers in prep.).

Polygon mesh: The point cloud can be used to display parts of the feature of which proper photographs could not be taken. This was particularly useful for the narrow wheel-races, with walls up to 5 m high; a polygon mesh was calculated. By changing the position of the light source, scratch marks produced by the water-wheels and the shape of sinter representing the course of the water, could be illustrated. Figure 8 shows one wall of a narrow wheel-race. The opposing wall leans towards the other wall,

making this already narrow wheel-race even more narrow and unstable.

Website: It was also decided to make selected 3D data and panoramic views available online. The user will be able to measure points and distances and also share them with other users. Figure 9 shows a screenshot of the web interface for displaying panoramic views. The design is almost the same as the platform envisaged for the point cloud. A schematic ground plan shows all available positions, helping with orientation. The user can either switch to another position by clicking on one of the dots in the ground plan, or by clicking on links provided in the panoramic views allowing a virtual tour through the workshop- and milling-complex. Work continues on the panoramic view: More information is being added in the form of short text and photos, helping the user to understand the feature. The web platform will be launched after the book is published (Wefers in prep.).

The point cloud was animated and published at www.rgzm.de/ephesos to convey to specialists and the public alike the size and location of the entire workshop and milling complex on a steep slope. To give a good idea of the original construction method and dimensions of this archaeological feature, the roughly shaped water-wheels were fitted into the 3D point cloud.

Furthermore, a digital 3D reconstruction based on the archaeological results was produced by the Department Informations- und Kommunikationstechnologie in der Architektur der Technische Universität Darmstadt. The lowest workshop of the entire visualisation, which is a water-powered stone sawing machine (Mangartz, 2010), is published as an animation on www.rgzm.de/ephsos.

4. CONCLUSIONS

In this project the 3D model, documenting the workshop and milling complex as accurately as possible with a 3D laser scanner, was very useful in archaeological research into the Terrace House 2 which was carried out not only in Turkey, but also in Germany. The research which had to be done in Ephesos, Turkey, could be much shorter, reducing the cost of the entire project. A 3D model does not replace archaeological fieldwork. Special archaeological questions may only be answered by examining the feature directly. The advantage of the 3D model is that it is possible to produce very detailed two-dimensional plans at any time. Such plans are very important to conveying the archaeological interpretation to other researchers. However, producing these plans was time-consuming, especially the development of a consistent and coherent map design and legend. Hopefully the resource will be helpful to future research into comparable features.

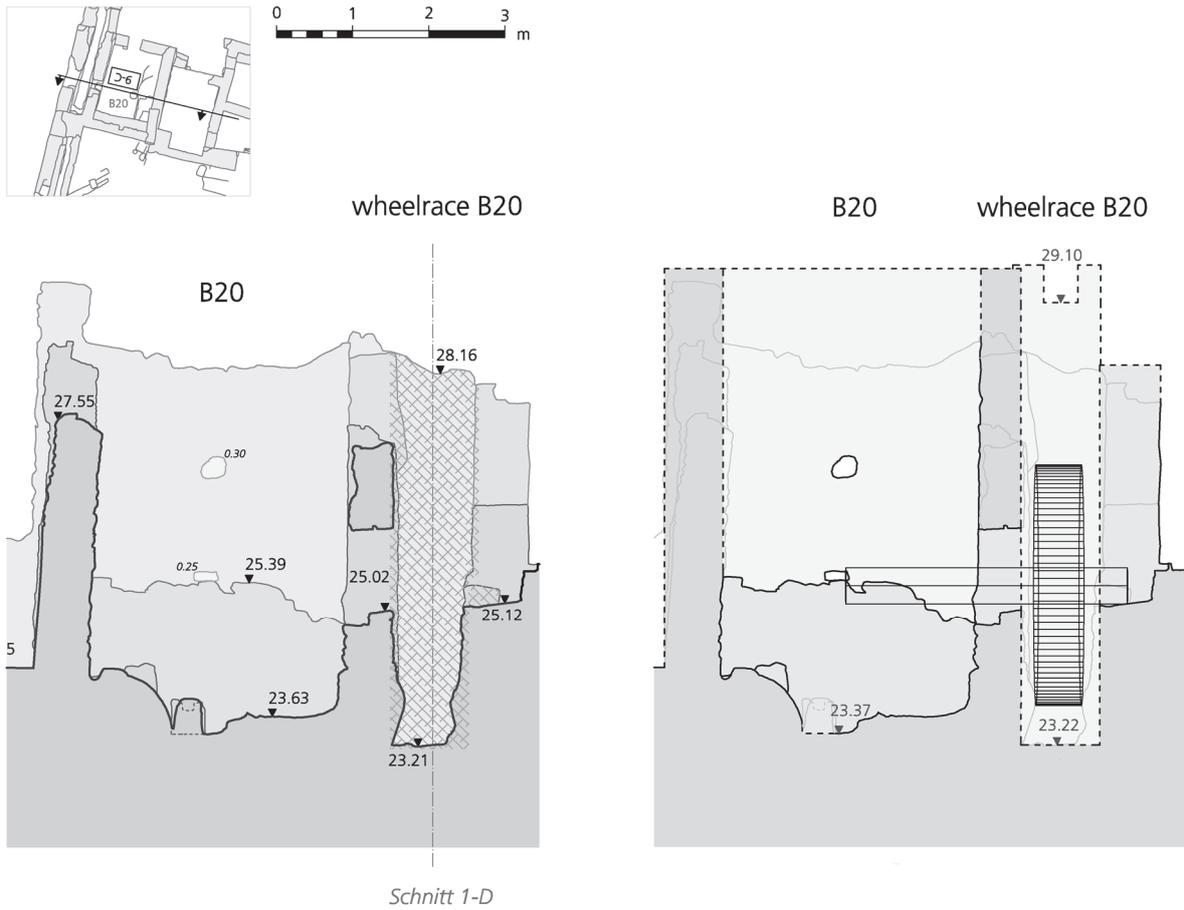


Figure 6. Section drawings of mill B20. Left: present state. Right: reconstruction of the mill with a schematic water-wheel, based on the archaeological interpretation.

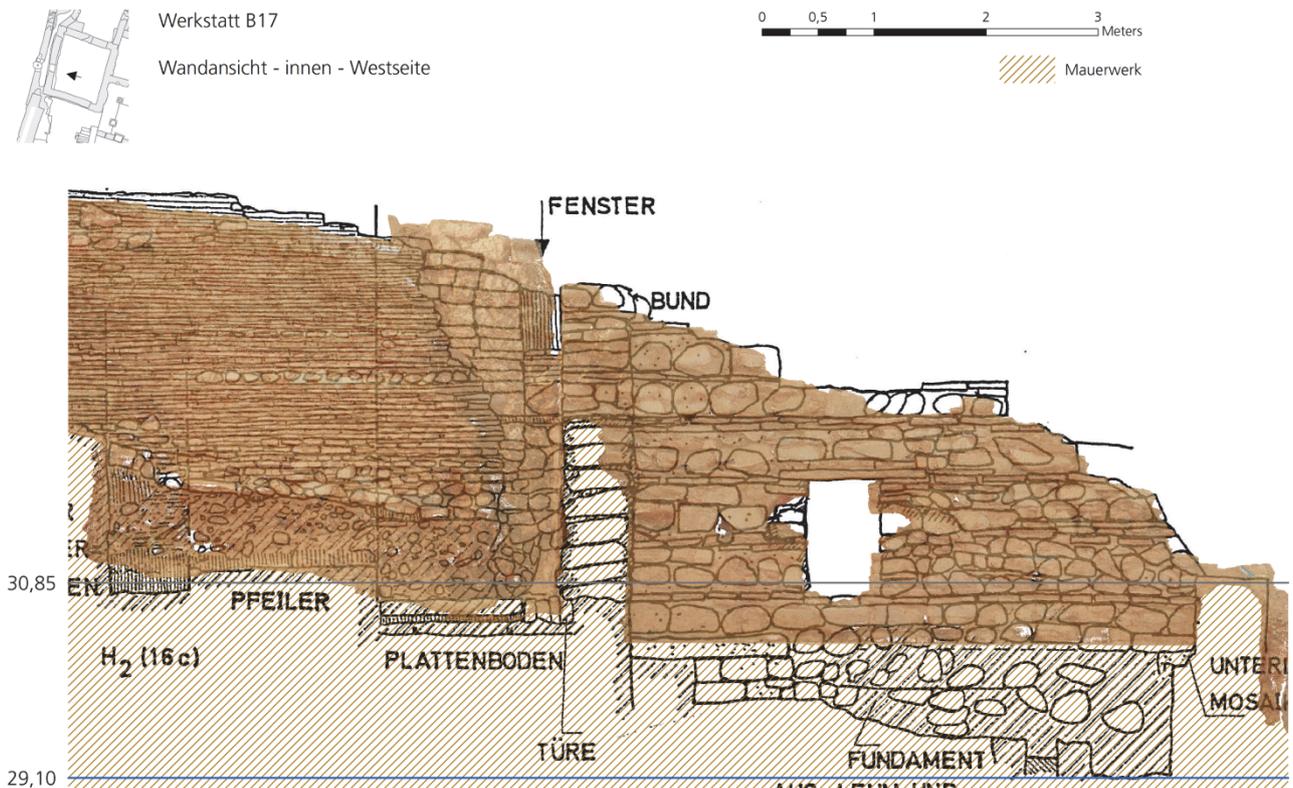


Figure 7. Combination of an old hand drawing of the wall of mill B17 (© ÖAI) and a projected point cloud of the same wall.

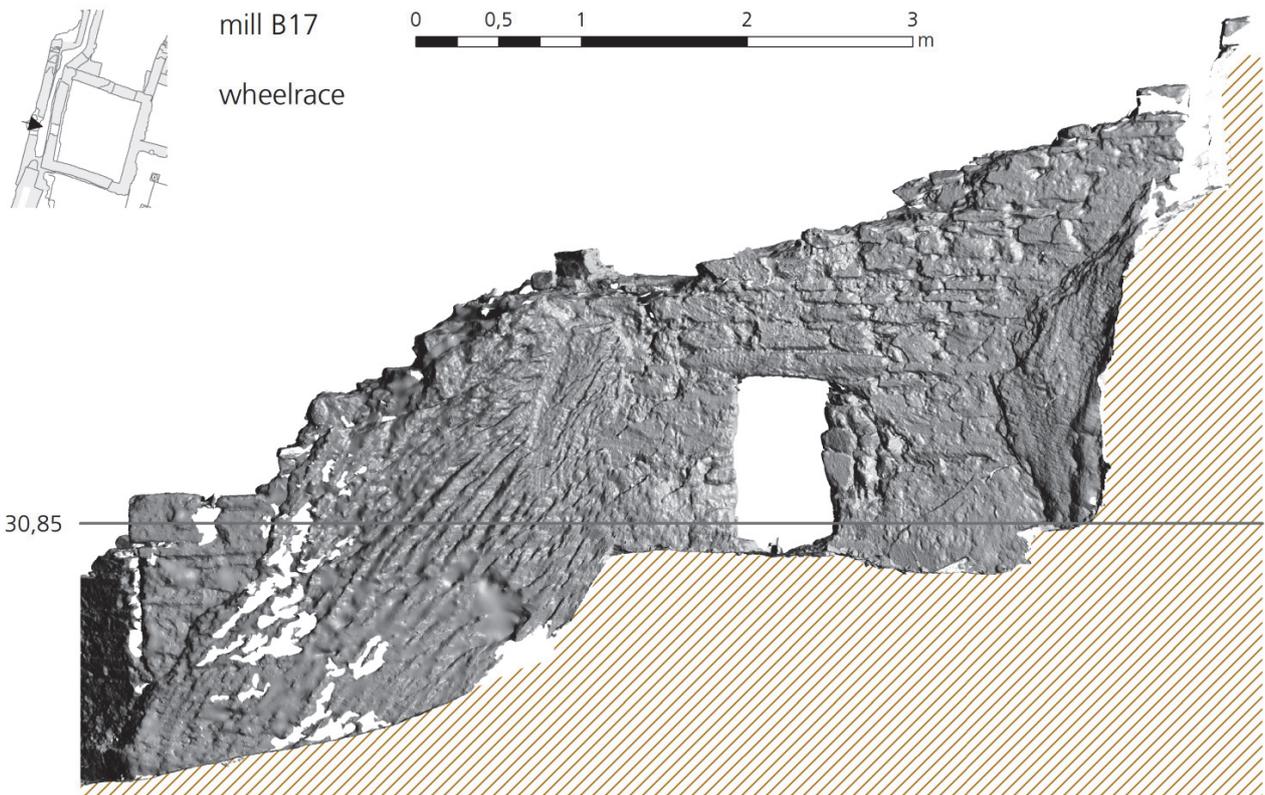


Figure 8. Shaded polygon mesh of the north-eastern wall of wheel-race B17.



Figure 9. Screenshot of the web interface for displaying panoramic views with dialogue boxes showing specific archaeological information in text or graphics of the workshop and milling complex in Ephesos.

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